Effect of Channel Exclusion for the Automatic Measurement of QT Dispersion in Multichannel Magnetocardiograms

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Abstract

Recent studies have indicated that multichannel magnetocardiograms (MCGs), which non-invasively measure cardiac magnetic field strength from many sites above the body surface, may provide independent information to ECGs about QT dispersion.

In this study QT dispersion measurement was investigated in 61-channel MCGs and 12-lead ECGs, recorded simultaneously using the Bochum multichannel SQUID system from 20 healthy volunteers. Two automatic methods for QT interval measurement were used to determine T wave end. QT dispersion, expressed as the QT interval range, was calculated across the 12 ECG leads and 61 MCG channels for each subject. MCG channels were then systematically excluded in random groups of 10 and QT dispersion was calculated for 51, 41, 31, 21 and 11 channels respectively.

Dispersion in the 61 channel MCG was significantly greater than 12 lead ECG by 39.1 (20.4) ms (mean (SD)) ($p < 0.00001$), across techniques and all subjects. Significant differences of 34.7 (18.7) ms ($p < 0.00001$), 29.6 (18.8) ms ($p < 0.00001$), 25.5 (21.3) ms ($p < 0.0002$) and 14.9 (21.0) ms ($p < 0.001$) were also obtained for the 51 to 21 channel data respectively. No significant differences were obtained for 11-channel data.

Automatic MCG dispersion measurements were significantly greater than dispersion from ECGs even when the number of MCG channels were reduced to 21 channels. However, small numbers of MCG channels need to be selected appropriately. The results suggest that a limited number of MCG channels is of value for repolarisation dispersion.

1. Introduction

There is some dispute over the diagnostic value of increased dispersion of ventricular repolarisation time (QT dispersion) in the electrocardiogram. [1] Recent studies have indicated that multichannel magnetocardiograms (MCGs), which are a measure of the variation in magnetic field strength above the thorax, may provide additional information to ECGs about QT dispersion. [2, 3]

MCGs may allow a more sensitive calculation of dispersion because of the intrinsic differences between cardiac electric and magnetic fields, permitting global as well as regional differences in repolarisation to be identified. Dispersion information from electrocardiography is limited because current flow from any single localised region produces an ECG effect at almost any body surface location. [4]

The aim of this study was to investigate and compare QT dispersion measurements from multichannel MCGs and simultaneously recorded 12-lead ECGs. Comparisons between MCG and ECG dispersion measurements were also made after systematically reducing the number of MCG channels from 61 to 11 channels.

2. Methods

2.1. Subjects

61-channel magnetocardiograms (MCGs) and 12-lead ECGs were recorded simultaneously from 20 healthy volunteers.

2.2. Data collection

MCGs were obtained using a multichannel SQUID magnetometer (Magnes 1300C, 4D Neuroimaging; San Diego) installed inside a magnetically shielded room (Akb3, Vakuumschmelze, Hanau), in Bochum, Germany. The magnetometer consisted of 61 channels for recording normal components of the magnetic field (Bz) arranged in

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a lattice on a plane covering an overall approximate circular area of diameter 31 cm and area of coverage of 800 cm^2. Figure 1 reflects the spatial arrangement of the 61 sensing channels.

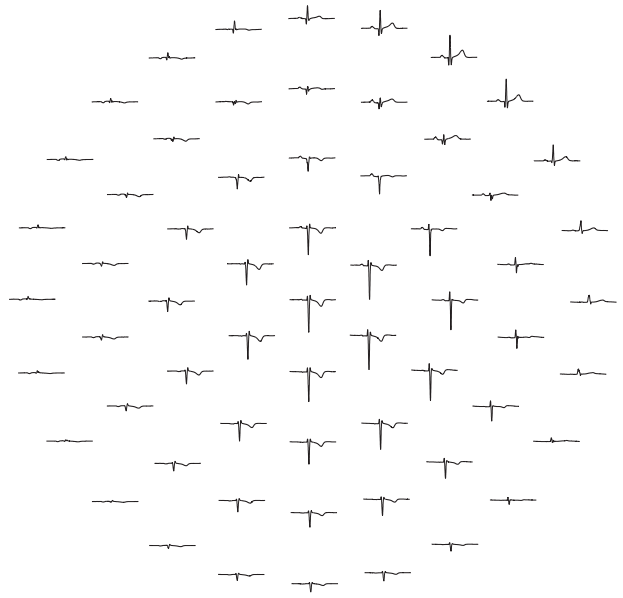

Figure 1. Example of the spatial arrangement of the 61 MCG signals for one heart-beat.

The multichannel device was placed as close to the chest as possible, directly over the heart. In addition, 12 lead ECGs were recorded simultaneously with MCGs using non-ferrous sintered silver/silver-chloride electrodes and non-magnetic connecting wires. MCG and ECG data were recorded for 5 minutes at a sampling rate of 1 kHz and with a bandpass of 0.1 – 200 Hz.

2.3. Automatic QT measurement

Computer software was developed in Matlab (Mathworks Inc.) to determine repolarisation measurements from two automatic techniques. [6]

The slope technique used a linear model, and T-wave end was determined from the intersection of the line of best fit of the T-wave section lying between 70% and 30% of the peak of the T-wave with the TP baseline.

The polynomial technique used a curve fitting method and T-wave end was determined from the minimum or maximum of a second order polynomial that was fitted to the 0.1 second section of the T-wave following the point at which the amplitude fell to half maximum.

2.4. Exclusion criteria

To reduce measurement error, small T-waves with amplitudes less than 1 pT for MCG and less than 0.1 mV for ECG were excluded from the study.

2.5. QT dispersion measurement

The standard clinical measurement of QT dispersion, maximum minus minimum QT, was calculated for all subjects and for each technique. The Mann-Whitney U test was used to determine the significance of differences between MCG and ECG for all comparisons made. A confidence level of 95 % was considered statistically significant.

2.6. Random selection of channels

MCG channels were systematically removed in random groups of 10 and QT dispersion was calculated for 61, 51, 41, 31, 21 and 11 channels respectively.

3. Results

3.1. Exclusions

Following application of exclusion criteria, the mean number of measured MCG channels was 48 (7) out of a maximum of 61 recorded. For the randomly selected channels, 41 (6) out of 51, 33 (6) out of 41, 26 (4) out of 31, 18 (2) out of 21, and 9 (2) out of 11 remained following exclusions.

3.2. QT interval

Figure 2 compares 61-channel MCG and 12-lead ECG QT interval measurements for the slope and polynomial techniques. Mean QT interval was 412 (34) ms for MCG and 395 (34) ms for ECG for the slope technique, with a Pearson correlation coefficient of 0.8. For the polynomial technique the mean QT interval for MCGs and ECGs was 455 (34) ms and 437 (32) ms respectively. Measurements between techniques were highly correlated with a Pearson correlation coefficient of 1.

When the automatic techniques were combined, the mean QT interval was 434 (34) ms for MCG and 416 (33) ms for ECG, with a Pearson correlation coefficient of 0.8. The combined technique was used for all subsequent analysis as there was no scientific reason for choosing one technique over the other.

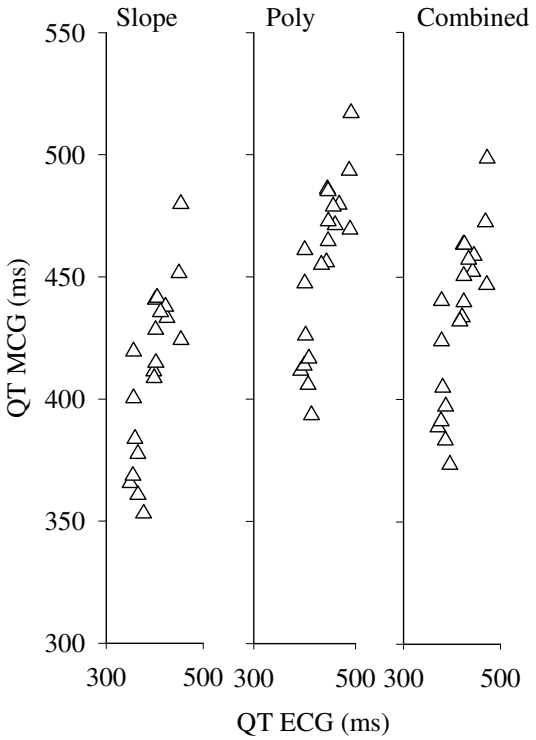

Figure 2. QT interval measurements for 61-channel MCG plotted against 12-lead ECG for both automatic techniques and the mean of both techniques.

3.3. QT dispersion

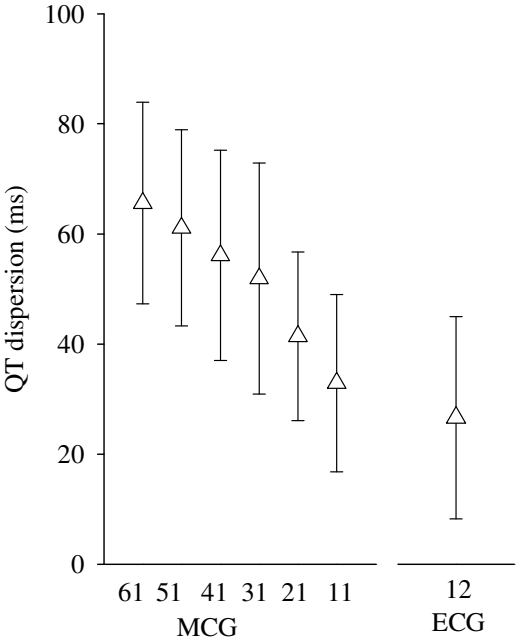

Figure 3. QT dispersion measurements for MCG (QTd_{MCG}) and ECG (QTd_{ECG}) for all subjects.

Figure 3 compares the QT dispersion measurements for 61-channel, 51-channel, 41-channel, 31-channel, 21-channel and 11-channel MCGs (QTd_{MCG}) and 12-lead ECGs (QTd_{ECG}).

Dispersion for 61-channel MCG was significantly greater than ECG by 39.1 (20.4) ms (mean (SD)) ($p < 0.00001$), across techniques and all subjects. Significant differences of 34.7 (18.7) ms ($p < 0.00001$), 29.6 (18.8) ms ($p < 0.00001$), 25.5 (21.3) ms ($p < 0.0002$) and 14.9 (21.0) ms ($p < 0.001$) were also obtained for the 51 to 21 channel data respectively, no significant differences were obtained for 11-channel data.

The paired differences between MCG and ECG dispersion are summarised in Figure 4.

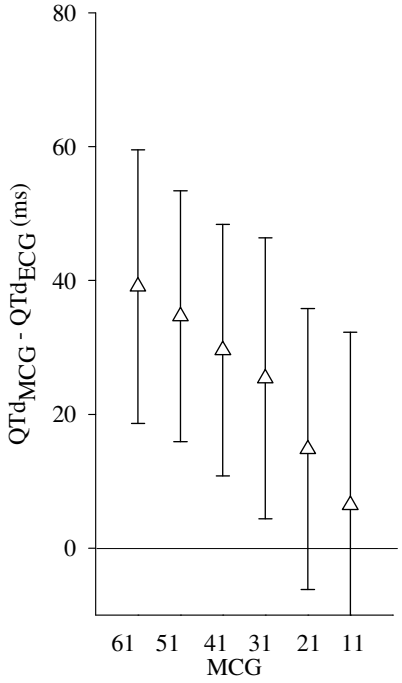

Figure 4. Differences between MCG and ECG QT dispersion for 61-channel ($p < 0.00001$), 51-channel ($p < 0.00001$), 41-channel (0.00001), 31-channel (0.0002), 21-channel (0.001) and 11-channel data.

4. Discussion and conclusions

This study compared automatic QT dispersion measurements from multichannel MCGs and 12-lead ECGs and also assessed the influence of reducing the number of MCG channels.

The most important results showed significantly different and greater QT dispersion measurements in the MCG even when the numbers of MCG channels were

randomly reduced to 21 channels. The significantly greater dispersion from MCGs indicates that MCG contains greater information about the dispersion of ventricular repolarisation than 12-lead ECGs. One possible explanation is that MCGs are more sensitive to tangential and vortex currents than ECGs and contain electrophysiological activity not contained in the ECG, and this may contribute to the more extreme QT intervals in MCGs. [6]

These findings are accepted in spite of some limitations that must be considered. Although significant differences between MCG and ECG channels were observed for multichannel MCG measurements, which included more registration sites not covered by the 12-lead ECG, small numbers of randomly selected MCG channels showed no significant differences. These results suggest that a reduced number of MCG channels require appropriate selection criteria to be applied.

In conclusion, using the standard clinical approach for repolarisation dispersion there were differences in automatic dispersion measurements between MCGs and ECGs even when the number of MCG channels were reduced to 21 channels. However, small numbers of MCG channels need to be selected carefully.

The results suggest that a limited number of MCG channels is of value for repolarisation dispersion.

Acknowledgements

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References

[1] Di Bernardo D, Langley P, Murray A. Dispersion of QT intervals:a measure of dispersion of repolarisation or simply a projection effect? PACE 2000;23:1392-1396.

[2] Van Leeuwen P, Hailer B, Wehr M. Spatial distribution of QT intervals: An alternative approach to QT dispersion. PACE 1996;19:1894-1899.

[3] Hänninen H, Takala P, Mäkijärvi M, Montonen J, Korhonen P, Oikarinen L, Simelius K, Nenonen J, Katila T, Toivonen L. Recording locations in multichannel magnetocardiography and body surface potential mapping sensitive for regional exercise-induced myocardial ischemia. Basic Res Cardiol 2001;96:405–414.

[4] Franz MR, Zabel M. Electrophysiological basis of QT dispersion measurements. Prog Cardiovasc Dis 2000;42:311-324.

[5] Smith FE, Langley P, Trahms L, Steinhoff U, Bourke JP, Murray A. Comparison of automatic repolarization measurement techniques in the normal magnetocardiogram. PACE 2003;26:2096-2102.

[6] Bradshaw LA, Richards WO, Wikswo JP Jr. Volume conductor effects on the spatial resolution of magnetic fields and electric potentials from gastrointestinal electrical activity. Med Biol Eng Comput 2001;39:35-43.

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